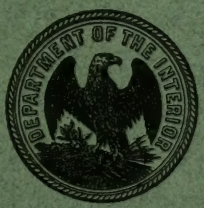
Bulletin 136

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary
BUREAU OF MINES
VAN. H. MANNING, Director

DETERIORATION IN THE HEATING VALUE OF COAL DURING STORAGE

BY

HORACE C. PORTER AND F. K. OVITZ



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DETERIORATION IN THE HEATING VALUE OF COAL DURING STORAGE.

By Horace C. Porter and F. K. Ovitz.

INTRODUCTION.

Much has been written of the changes undergone by coal in storage and the deterioration of coal through exposure to the weather. In order to obtain definite information for the benefit of the Government departments and of all who store coal in large quantities, a series of tests was begun in the fall of 1909 under the supervision of J. A. Holmes, then chief technologist of the United States Geological Survey, and was continued by the Bureau of Mines after its establishment in 1910. The tests were confined to determinations of the loss in heating value of the coals and did not include a study of other deterioration; for example, in coking quality or the yield of by-products in coking. The Bureau of Yards and Docks of the Navy Department cooperated in tests of New River (W. Va.) coal, a variety largely used by the Navy. A preliminary report presenting a brief account of the early results of these tests has been published by the Bureau of Mines as Technical Paper 16.[a]

The detailed report is presented in this bulletin, which gives a full account of the tests and the analytical data covering a period of five years' storage. Data of somewhat similar experiments for shorter periods with gas coal from the Pittsburgh bed, with Pocahontas coal on the Isthmus of Panama, and with Sheridan, Wyo., subbituminous coal, which is used for railroad and other purposes in the West, are included.

The tests of New River coal, in cooperation with the Navy Department, were undertaken to determine the advantage to be gained by storing coal under water, and particularly under salt water. Small lots were used in order to make the tests of maximum severity, and parallel experiments were made with run-of-mine and crushed coal under one-fourth inch size. All of the small lots tested under the different conditions (except those tested near Key West, Fla.) were taken as representative portions from one large original lot.

The tests of Pocahontas coal, which, like the New River, is semibituminous, were undertaken chiefly to determine the effect of the

[a] Porter, H. C., and Ovitz, F. K., Deterioration and spontaneous heating of coal in storage, 1912, 13 pp.

tropical conditions in Panama. They were made on an outdoor pile of 100 tons of run-of-mine coal.

Pittsburgh gas coal, a high-volatile, bituminous type used at gas and by-product coke works, was exposed for test at Ann Arbor, Mich., in cooperation with the University of Michigan. The university agreed to make tests at successive intervals of storage to determine, in its illuminating-gas experiment station, the yields of gas and by-products from the coal. The coal, screened lump, was stored in about 4-ton lots out of doors in open bins.

Subbituminous coal, which is mined in Colorado, Wyoming, and other States, and is known also as "black lignite," is commonly supposed to deteriorate rapidly in storage, especially by "slacking" or crumbling of the lumps. The tests herein described were undertaken at Sheridan, Wyo., in cooperation with the Chicago, Burlington & Quincy Railroad Co., in order to determine the extent of this slacking and the accompanying loss of heat value. The tests were in open bins holding 4 to 12 tons.

GENERAL SUMMARY OF RESULTS.

The results of all these tests are to be taken as showing only the change in heating value and approximately, also, the degradation of lumps by weathering; as to any resultant deadening effect or decrease of original ease of burning, no examination or test was made.

In brief, it may be said, the tests show that the amount of deterioration of coal in heating value during storage has commonly been overestimated. Except for the subbituminous Wyoming coal, no loss was observed in outdoor weathering greater than 1.2 per cent in the first year, or 2.1 per cent in two years. The Wyoming coal suffered somewhat more loss, 2 to 3 per cent in the first year and as much as 5.5 per cent in three years. Details are given under the separate headings.

ACKNOWLEDGMENTS.

Acknowledgment is due to the commandants of the United States navy yards at Portsmouth, N. H., and Norfolk, Va., and of the United States naval station at Key West, Fla., for their cooperation and assistance in the tests on New River coal; to Prof. A. H. White and his assistants at the University of Michigan for carrying out the sampling in the tests of Pittsburgh coals; and to the officials of the Panama Railroad Co., and the Chicago, Burlington & Quincy Railroad Co. for cooperation in the tests of Pocahontas coal and those of Sheridan, Wyo., coal, respectively. The analytical laboratory at the Pittsburgh experiment station of the Bureau of Mines, under the direction of A. C. Fieldner, chemist, performed a large part of the analyses connected with the tests.

TESTS OF NEW RIVER COAL.

Briefly summarized, the tests show that submergence storage of New River coal effectively prevents deterioration of calorific value, and that storage of that coal in the open air causes only slight deterioration, about 1 per cent in one year's exposure and about 2 per cent in two years. After two years, the loss of heating value is continuous but very slow, reaching about 2.5 to 3 per cent in five years. With New River coal, therefore, the expense of underwater storage equipment is not justified except as an absolute preventive of fires from spontaneous combustion.

SOURCE AND PREPARATION OF THE COAL.

The coal used in the tests was from the Sun mine, working the Sewell bed in the New River district, Fayette County, W. Va., and was mined especially for this purpose, under the supervision of a Government mining engineer. An endeavor was made to obtain coal representing the commercial output of the mine.

Small quantities of coal, which in the majority of tests was finely crushed, were used for the express purpose of making the tests of maximum severity and in order to facilitate sampling.

On August 27, 1909, one lot of 3 to 4 tons of run-of-mine coal was collected at the mine and shipped in sacks to Washington, D. C. Three mine samples were taken at the same time from the faces from which the coal was mined, and were mailed at once in sealed cans to the laboratory for analysis. The test coal remained 16 days in the sacks, and then a representative portion, about 2 tons, was crushed to pass a one-fourth-inch screen, mixed well, and divided into small test portions for storing. Each of these portions was reduced by quartering and carefully sampled. Eighteen 50-pound lots of one-fourth-inch coal were placed in heavy wooden boxes for submergence under water. These boxes were lined with canvas and perforated with three-fourths-inch holes to facilitate displacement of the air during submergence. Eight lots of the crushed coal, 300 to 350 pounds each, were placed in barrels. From the balance of the original lot of coal, eight portions, also run-of-mine, were placed in barrels. Each barrel was sampled as thoroughly as possible by taking a number of well-distributed portions of lump and fine, then crushing and reducing these by quartering.

These test portions of coal as prepared in Washington were shipped by freight to the Portsmouth, N. H., and Norfolk, Va., navy yards, and to the experiment station of the Bureau of Mines at Pittsburgh, Pa. Table 1 gives the essential data as to number of portions stored.

On December 14, 1909, another lot of coal was collected from the same mine for storage near Key West, Fla. The mining, preparation,

and sampling of the coal were carried out as before, except that a longer time (47 days) elapsed between the mining of the coal and sampling, thereby allowing greater deterioration before the beginning of the tests. Wooden boxes used for the submergence tests near Key West were made of lumber that had been creosoted in order to prevent, if possible, destruction by the teredo. Some of these boxes remained intact, for the purposes of the test, during submergence for three and one-half years.

TABLE 1.—*Conditions of storage of New River, W. Va., coal.*

Location of test.	Days between mining and sampling.	Days between sampling and storing.	Size of coal.	Number of portions of—			
				Coal in boxes submerged under sea water.	Coal in barrels submerged under fresh water.	Coal exposed indoors.	Coal exposed outdoors.
Pittsburgh, Pa...	16	34	¼-inch		1	1	2
			Run-of-mine		1	1	2
Portsmouth, N.H.	16	85	¼-inch	9		1	1
			Run-of-mine			1	1
Norfolk, Va.....	16	41	¼-inch	9		1	1
			Run-of-mine			1	1
Key West, Fla...	47	27	¼-inch	10		1	1
			Run-of-mine			1	1

STORING THE COAL.

At Pittsburgh, Pa., eight barrels of coal were placed in storage on September 30, 1909, as follows: One barrel of ¼-inch coal and one of run-of-mine were filled with fresh water so as to submerge the coal; one barrel of each grade, dry, was placed indoors loosely covered, and two barrels of each grade were emptied in separate piles, fully exposed to the weather, on the roof of a building at the Bureau of Mines experiment station.

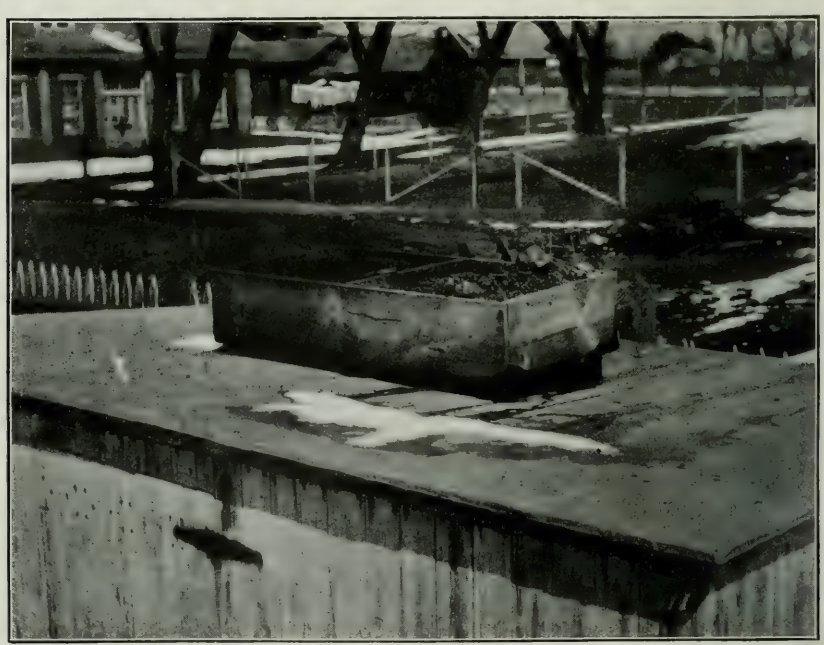
At Portsmouth, N. H., nine boxes and four barrels were placed in storage at the navy yard on November 20, 1909. These test portions had stood at the yard in their closed containers from September 20 to November 20. The nine boxes were placed in a larger box, which was sunk under the full salt water of the dry dock basin until it rested on the granite bottom. (See Pl. I.) The small test boxes were entirely submerged at all times, although the large box containing them was partly out of water at low tide. One barrel of ¼-inch coal and one of run-of-mine, both with heads removed, were placed on a platform in the fire-engine house (see Pl. II, *A*), and one barrel of each grade was emptied in an open pile on the roof of a small shed, where it was fully exposed to the weather (see Pl. II, *B*).

At Norfolk, Va., nine boxes and four barrels were placed in storage at the navy yard on October 7, 1909. The boxes were submerged by chaining them to the pier at a depth insuring complete submer-

A. WEIGHTED BOX CONTAINING SMALLER BOXES OF NEW RIVER COAL SUBMERGED UNDER SALT WATER AT PORTSMOUTH, N. H.

B. DRY-DOCK BASIN, PORTSMOUTH, N. H., WHERE BOXES OF NEW RIVER COAL WERE SUBMERGED.

A. BARRELS OF NEW RIVER COAL EXPOSED INDOORS AT PORTSMOUTH, N. H.



B. NEW RIVER COAL EXPOSED TO WEATHER AT PORTSMOUTH, N. H.

gence at all tides (see Pl. III, *A*). The portions for open-air tests indoors were emptied from the barrels into open boxes on platforms, especially made for the purpose inside of one of the navy yard buildings (see Pl. III, *C*); and the outdoor open-air tests were similarly arranged outside one of the buildings (see Pl. III, *B*).

Near Key West, Fla., the test portions were placed in storage at Fort Jefferson, Dry Tortugas, on February 25, 1910, a special lot of coal having been collected for them nearly four months after the collection of the first lot. Ten creosoted boxes were submerged in the moat, one barrel of each grade was placed indoors in a casemate, and one of each set was put outside on the parapet, exposed to the weather. Two months later, on April 25, the outside test portions were emptied from the barrels into open piles. Early in January, 1911, 10 months after storing, the open-air test piles were scattered by a storm and lost. The two barrels that had been stored indoors were then emptied into outdoor piles to replace those lost.

At Portsmouth, N. H., the tests were under the immediate supervision of U. S. G. White, civil engineer, United States Navy, during the first few months of their progress, and of L. E. Gregory, civil engineer, United States Navy, thereafter. At Dry Tortugas, Fla., they were carried out by George C. Short, mate, United States Navy, under the direction of the commandant of the station. At Norfolk, Va., a representative of the Government fuel inspection service directed the starting of the tests and the subsequent sampling.

SAMPLING THE COAL.

Samples of each portion were taken periodically and the successive analyses were compared separately. During the first year, samples were taken every three months, during the second year every six months, and thereafter every year. The submerged boxes were sampled in rotation; that is, at three months box 1 was sampled, at six months box 2, and so on, in order to avoid repeated exposure of the coal. In addition, one particular box was repeatedly sampled in order to determine the effect, if any, of this periodical exposure on the deterioration. Thus at each sampling time two boxes were raised from the water, one was immediately replaced, the other was emptied. The wet coal in the latter was spread out in the open air for 24 hours, then sampled and replaced.

The submerged fine coal was sampled by the customary quartering method, the entire lot being spread out and reduced, by repeated quartering and rejection of alternate quarters, to a sample of convenient size for mailing, about 2 to 3 pounds. The barrel lots exposed to the air were not sampled in the same way because the coal would thus have been repeatedly turned over at each sampling time and unduly exposed as compared with usual storage conditions. Instead, samples were taken by selecting at random six or eight well-

distributed portions of 2 pounds each, then mixing and quartering them. From the run-of-mine coal, half of these selected portions were pieces broken from lumps, the balance being from the finer coal. Before quartering, all lumps were crushed to ½-inch size. In most cases duplicate samples were taken from each lot.

ANALYSIS OF THE COAL SAMPLES.

All coal samples taken during the first two years' progress of the tests were analyzed at the laboratory of the Pittsburgh experiment station, the calorimetric determinations being made throughout by the same man and with the same calorimeter. Each sample was analyzed for moisture, ash, and sulphur, and its calorific value determined. A number of composite samples were subjected to a complete ultimate analysis for carbon, hydrogen, oxygen, nitrogen, and sulphur. The methods used were those described in Technical Paper 8[a] of the bureau.

"UNIT COAL" THE BASIS OF COMPARISON OF VALUES.

In studying the deterioration of coal the important practical problem is to determine the change in the dry organic substance. The incidental ingredients—sulphur, ash, and moisture—that accompany the coal substance affect the calorific value of a coal, but any changes that they may undergo have nothing to do with the alteration of the coal substance itself. For example, a coal wetted by exposure has its apparent calorific value reduced through the addition of water, whereas on the basis of dry material its fuel value may be unaltered. Furthermore, as to ash and sulphur, it is not practicable, by use of the sampling methods adopted in these tests, to obtain from the same lot of coal, even in ¼-inch size, successive samples in which the aggregate percentages of these ingredients will always agree within 0.5 per cent. In other words, determination of calorific values of a stored coal might seem to show a deterioration of, say, 0.5 per cent, when in fact all of this change could be accounted for by the different moisture or ash content of the samples.

This investigation, therefore, endeavors to show merely the extent of deterioration in the actual coal substance, which in this paper is termed "unit coal." The calorific values as determined are all reduced to this basis—eliminating the effect of moisture, ash, and sulphur—by the following formula;

$$W=\frac{w-2620S}{1.00-[(M+A+\frac{5}{8}S+0.04\,(A-\frac{1}{8}S)]}$$

in which W = calories on unit coal basis, w = determined calories, M = moisture, A = ash, and S = sulphur.

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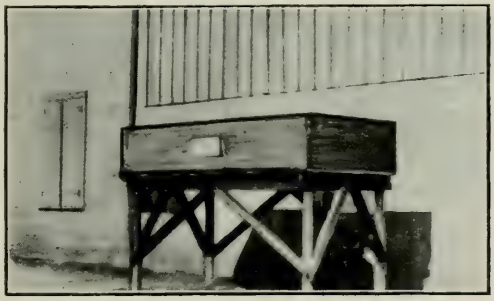
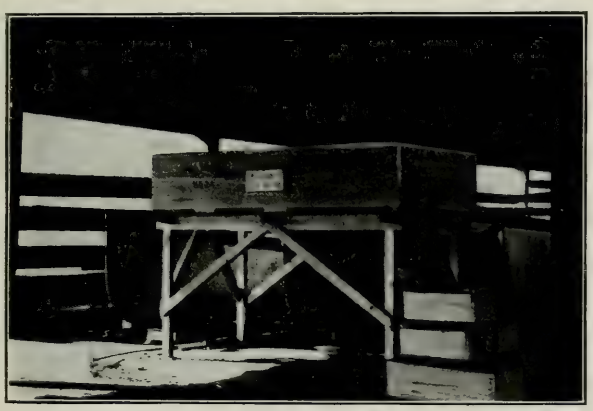
[a] Stanton, F. M., and Fieldner, A. C., Methods of analyzing coal and coke: Tech. Paper 8, Bureau of Mines, 1913, 42 pp.

A. DOCK UNDER WHICH BOXES OF NEW RIVER COAL WERE SUBMERGED AT NORFOLK, VA.

Black cross indicates spot under which boxes were chained to the piles.



B. OUTDOOR EXPOSURE OF NEW RIVER COAL AT NORFOLK, VA.



C. EXPOSURE OF NEW RIVER COAL UNDER SHELTER AT NORFOLK, VA.

As sulphur has a positive calorific value, its theoretical heat of combustion when in the form of iron pyrites, 2,620 calories, is subtracted from the determined calorific value. The expression below the line in the formula represents the percentage of "unit coal" in the sample, the moisture, ash, and sulphur being subtracted from 100 per cent. The expression, $A+\frac{5}{8}S+0.04\ (A-\frac{1}{8}S)$ is based on the assumption that all the sulphur is present as FeS_2 (iron pyrites) and that therefore the ash content determined must be corrected for the decrease in weight due to burning FeS_2 to Fe_2O_3—this decrease being five-eighths of the sulphur—and on the further assumption that the ash as determined is less than the true original ash by the amount of combined water driven out of clay and shale, roughly 4 per cent of the pyrite-free ash. These assumptions are based on a chemical examination of the shale and sulphur partings of the coal bed in the mine from which this coal was obtained.

WEATHER CONDITIONS.

Weather conditions varied at the different storage points, the tests being more severe at Key West and Norfolk than at Portsmouth and Pittsburgh. Table 2 shows average temperature conditions in air and water at the different points throughout the first two years of the tests.

TABLE 2.—*Monthly temperature averages (°F.) of air and water.*

[P.=Portsmouth, N. H.: Pgh.=Pittsburgh; N.=Norfolk; K. W.=Key West (Dry Tortugas).]

Month.	Temperature of air.								Temperature of water.			
	Average.				Maximum.				Average.			
	P.	Pgh.	N.	K.W.	P.	Pgh.	N.	K.W.	P.	Pgh.[a]	N.	K.W.[b]
1909.												
October	51.1	49.6	58.4	77.4	85	80	79	88	.....	85	.....	78
November	43.5	50.4	55.0	73.4	72	73	76	82	.....	90	57	77
December	28.6	26.8	38.8	69.2	52	65	64	81	.....	60	42	71
1910.												
January	28.5	30.8	41.6	67.1	51	51	69	80	.....	55	43	68
February	25.4	28.6	43.2	69.0	54	55	76	81	.....	55	41	67
March	39.4	48.8	55.0	71.3	74	83	90	81	39	60	51	69
April	48.5	52.8	60.0	74.2	68	83	87	83	47	65	60	72
May	55.8	57.8	65.2	78.4	78	83	90	87	50	70	66	77
June	65.4	67.0	72.0	81.9	90	90	92	89	57	75	74	81
July	74.7	74.9	78.4	82.8	94	91	93	90	61	75	81	82
August	69.4	72.8	76.4	83.1	90	90	90	92	60	73	81	83
September	62.7	67.6	73.4	81.4	83	86	92	90	59	70	77	82
October	54.6	57.6	63.8	77.8	87	84	86	87	53	70	70	79
November	40.9	37.1	45.4	70.4	59	63	71	79	46	65	49	73
December	26.2	27.0	37.2	65.3	51	55	66	78	37	60	39	70
1911.												
January	28.3	35.2	45.0	70.3	56	60	72	80	35	60	42	66
February	24.0	35.3	43.8	71.5	46	64	71	82	33	60	45	67
March	32.8	37.1	47.0	73.5	55	66	77	84	36	65	47	69
April	44.7	48.1	54.6	77.1	83	78	80	85	40	65	56	75
May	61.9	68.0	69.2	77.6	99	93	94	86	49	65	68	77
June	65.1	71.0	75.6	81.8	93	94	98	89	56	70	77	80
July	76.6	75.4	79.2	82.2	106	100	97	90	60	75	83	83
August	69.3	73.8	78.8	82.0	93	97	94	90	58	75	81	83
September	62.0	68.0	74.4	82.5	87	86	88	90	56	70	79	82
October	52.0	54.2	62.6	81.8	73	77	89	89	50	70	68	81

[a] Estimated. The barrels of coal were transferred in December, 1909, from a warm room to a cooler one.
[b] Estimated, except in January, April, and July, 1911, when observations were made on single days.

RESULTS OF STORAGE TESTS.

Results of storage tests are shown in Tables 3 to 16 following:

TABLE 3.—*Storage tests of New River, W. Va., coal, ¼-inch crushed, submerged under sea water, at Portsmouth, N. H., in 50-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
			P. ct.	*P. ct.*	*P. ct.*					*P. ct.*
Mine sample	Aug. 27, 1909	3	3.46	3.50	0.66	8,438	15,188	8,773	15,792	.....
As stored:										
Box 1	Sept. 12, 1909	2	1.98	4.03	.74	8,361	15,050	8,747	15,745	.....
2	.....do.....	2	1.84	4.39	.76	8,343	15,018	8,763	15,774	.....
3	.....do.....	2	2.07	5.99	.93	8,183	14,729	8,750	15,750	.....
4	.....do.....	2	2.14	5.00	.78	8,288	14,918	8,761	15,770	.....
5	.....do.....	2	2.18	5.14	.92	8,277	14,899	8,769	15,784	.....
6	.....do.....	2	1.92	4.27	.76	8,357	15,043	8,764	15,775	.....
7	.....do.....	2	1.39	4.88	.76	8,298	14,936	8,759	15,767	.....
8	.....do.....	2	1.79	5.89	.94	8,196	14,752	8,755	15,759	.....
9	.....do.....	2	1.72	4.75	.88	8,298	14,937	8,752	15,754	.....
After 4 months:										
Box 1	Jan. 3, 1910	1	19.77	7.60	2.28	7,986	14,375	8,730	15,714	0.2
After 6 months:										
Box 2	Apr. 15, 1910	1	14.83	6.21	.95	8,113	14,603	8,700	15,660	.7
9	.....do.....	2	5.65	5.84	.91	8,167	14,701	8,715	15,687	.4
After 9 months:										
Box 3	July 19, 1910	1	16.68	6.27	.90	8,151	14,672	8,744	15,739	.1
9	.....do.....	2	14.74	4.76	.80	8,300	14,939	8,751	15,752	.....
After 1 year:										
Box 4	Oct. 11, 1910	2	17.42	4.33	.75	8,347	15,025	8,759	15,765	.....
9	.....do.....	2	13.71	3.94	.71	8,396	15,112	8,773	15,791	*a*.2
After 1½ years:										
Box 5	Apr. 7, 1911	2	19.91	7.08	1.28	8,047	14,485	8,724	15,703	.5
9	.....do.....	2	17.57	6.52	1.01	8,095	14,571	8,711	15,680	.5
After 2 years:										
Box 6	Oct. 10, 1911	1	16.01	5.54	.83	8,201	14,762	8,724	15,703	.5
9	.....do.....	2	18.72	6.60	.94	8,111	14,599	8,733	15,719	.2
After 3 years:										
Box 7	Oct. 17, 1912	2	18.39	5.97	1.01	8,134	14,641	8,698	15,614	1.0
9	.....do.....	1	22.22	7.37	1.14	7,958	14,324	8,648	15,566	1.2
After 4 years:										
Box 8	Oct. 6, 1913	2	17.72	7.40	1.19	8,019	14,434	8,718	15,692	.4
9	.....do.....	2	21.58	8.34	1.17	7,909	14,236	8,689	15,640	.6
After 5 years:										
Box 8	Oct. 17, 1914	2	17.93	8.49	1.30	7,922	14,259	8,723	15,701	.4

a Gain.

TABLE 4.—*Storage tests of New River, W. Va., coal, exposed indoors at Portsmouth, N. H., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run of mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.75	4.45	0.69	8,332	14,998	8,574	15,757	.....
After 3 months	Jan. 3, 1910	1	.67	4.82	1.33	8,282	14,908	8,753	15,755	0.0
1 year	Oct. 11, 1910	2	1.19	2.94	.46	8,469	15,254	8,748	15,746	.1
1½ years	Apr. 7, 1911	2	.70	6.28	1.28	8,115	14,606	8,713	15,683	.5
2 years	Oct. 10, 1911	2	1.01	3.98	.74	8,350	15,029	8,728	15,710	.3
3 years	Oct. 11, 1912	2	.98	5.34	1.09	8,168	14,703	8,675	15,615	.9
4 years	Oct. 8, 1913	2	.98	6.25	1.33	8,085	14,553	8,681	15,625	.8
5 years	Oct. 17, 1914	2	1.15	5.73	.94	8,124	14,623	8,663	15,593	1.0
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	1.79	6.27	.84	8,185	14,733	8,779	15,802	.....
After 3 months	Jan. 3, 1910	1	.92	7.82	.94	7,966	14,339	8,724	15,703	.6
1 year	Oct. 11, 1910	2	1.22	5.64	.70	8,213	14,783	8,742	15,736	.4
1½ years	Apr. 7, 1911	2	.79	6.68	.86	8,096	14,572	8,721	15,679	.7
2 years	Oct. 10, 1911	2	1.23	7.14	.97	8,034	14,460	8,703	15,666	.9
3 years	Oct. 11, 1912	2	1.02	6.42	.94	8,067	14,521	8,667	15,601	1.3
4 years	Oct. 8, 1913	2	1.04	6.93	1.01	7,995	14,391	8,641	15,554	1.6
5 years	Oct. 17, 1914	2	1.19	6.84	1.02	8,012	14,422	8,652	15,573	1.4

TABLE 5.—*Storage tests of New River, W. Va., coal exposed to weather at Portsmouth, N. H., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.81	5.34	0.70	8,271	14,888	8,775	15,795	.....
After 3 months	Jan. 3, 1910	1	3.22	4.89	1.23	8,282	14,908	8,757	15,763	0.2
6 months	Apr. 15, 1910	1	1.44	2.67	.52	8,486	15,275	8,742	15,736	.4
9 months	July 19, 1910	2	1.38	5.02	.64	8,265	14,876	8,738	15,725	.4
1 year	Oct. 11, 1910	2	2.32	2.20	.34	8,551	15,392	8,760	15,768	.2
1½ years	Apr. 7, 1911	2	2.43	2.41	.52	8,507	15,313	8,738	15,728	.4
2 years	Oct. 10, 1911	2	2.33	3.61	.38	8,378	15,080	8,716	15,688	.7
3 years	Oct. 11, 1912	2	4.50	3.67	.71	8,333	14,999	8,681	15,625	1.1
4 years	Oct. 7, 1913	2	3.07	4.18	.62	8,293	14,928	8,684	15,632	1.0
5 years	Oct. 17, 1914	2	3.45	3.53	.54	8,318	14,973	8,648	15,567	1.4
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	2.01	6.68	1.02	8,116	14,609	8,748	15,747	.....
After 3 months	Jan. 3, 1910	2	3.10	7.29	1.27	8,028	14,451	8,720	15,695	.3
6 months	Apr. 15, 1910	1	2.00	6.48	1.03	8,111	14,600	8,726	15,707	.3
9 months	July 19, 1910	2	1.93	6.70	1.07	8,085	14,553	8,719	15,694	.3
1 year	Oct. 11, 1910	2	3.75	6.94	.94	8,051	14,491	8,701	15,661	.5
1½ years	Apr. 7, 1911	2	10.50	6.67	1.00	8,059	14,506	8,685	15,633	.7
2 years	Oct. 10, 1911	2	17.42	7.04	.75	8,016	14,429	8,668	14,603	.9
3 years	Oct. 11, 1912	2	12.86	6.91	.92	7,995	14,390	8,637	15,547	1.3
4 years	Oct. 7, 1913	2	16.23	6.90	.72	8,004	14,407	8,641	15,553	1.2
5 years	Oct. 17, 1914	2	13.09	7.92	.77	7,908	14,234	8,637	15,547	1.3

TABLE 6.—*Storage tests of New River, W. Va., coal, ¼-inch crushed, submerged under sea water at Norfolk, Va., in 50-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u.
As stored:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
Box 10	Sept. 12, 1909	2	2.00	5.20	0.96	8,272	14,891	8,772	15,790	.....
11	....do....	2	2.01	6.45	.99	8,130	14,635	8,742	15,736	.....
12	....do....	2	1.99	5.13	.82	8,260	14,867	8,744	15,739	.....
13	....do....	2	1.80	5.42	.93	8,237	14,827	8,754	15,757	.....
14	....do....	2	1.64	5.44	1.03	8,234	14,821	8,754	15,757	.....
15	....do....	2	1.86	5.22	.81	8,269	14,894	8,764	15,775	.....
16	....do....	2	1.64	5.12	.70	8,262	14,872	8,745	15,741	.....
17	....do....	2	1.80	5.33	.88	8,239	14,831	8,745	15,740	.....
After 3 months:										
Box 10	Jan. 11, 1910	2	17.54	5.82	1.05	8,191	14,744	8,747	15,745	0.3
After 6 months:										
Box 10	Apr. 7, 1910	2	10.47	5.72	.99	8,190	14,743	8,733	15,720	.4
11	....do....	1	15.52	6.34	1.11	8,140	14,653	8,744	15,739	.0
After 10 months:										
Box 10	July 13, 1910	2	18.06	5.35	.92	8,248	14,846	8,757	15,763	.2
12	....do....	1	16.62	4.56	.74	8,310	14,958	8,744	15,739	.0
After 1 year:										
Box 10	Oct. 4, 1910	2	14.94	5.72	.95	8,193	14,748	8,737	15,725	.4
13	....do....	1	17.35	4.34	.82	8,345	15,021	8,763	15,773	[a].1
After 1½ years:										
Box 10	Apr. 4, 1911	2	20.63	6.67	1.13	8,105	14,588	8,738	15,729	.4
14	....do....	1	19.71	6.69	1.28	8,114	14,605	8,756	15,761	.0
After 2 years:										
Box 10	Oct. 4, 1911	2	18.92	8.01	1.12	7,968	14,344	8,719	15,695	.6
15	....do....	1	20.47	6.55	.93	8,108	14,593	8,725	15,705	.4
After 3 years:										
Box 10	Oct. 15, 1912	2	24.16	11.03	1.27	7,641	13,753	8,663	15,594	1.2
16	....do....	1	16.46	6.92	.97	8,047	14,485	8,696	15,653	.6
After 4 years:										
Box 17	Oct. 10, 1913	1	20.98	6.77	1.08	8,069	14,524	8,708	15,674	.4
After 5 years:										
Box 17	Oct. 8, 1914	1	24.62	7.91	1.15	7,957	14,323	8,701	15,662	.5

[a] Gain.

TABLE 7.—*Storage tests of New River, W. Va., coal exposed indoors at Norfolk, Va., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.61	4.14	0.77	8,348	15,027	8,743	15,737	.....
After 3 months	Jan. 11, 1910	1	1.37	4.39	.65	8,349	15,029	8,764	15,775	[a]0.2
6 months	Apr. 7, 1910	2	1.14	3.93	.65	8,367	15,061	8,739	15,729	.1
9 months	July 13, 1910	2	1.43	5.60	.84	8,202	14,762	8,732	15,718	.1
1 year	Oct. 4, 1910	2	1.47	5.10	.71	8,246	14,843	8,725	15,705	.2
1½ years	Apr. 4, 1911	2	1.49	4.70	.73	8,282	14,658	8,727	15,709	.2
2 years	Oct. 4, 1911	2	1.33	5.35	.75	8,221	14,798	8,724	15,703	.2
3 years	Oct. 15, 1912	2	4.67	5.18	.88	8,207	14,773	8,696	15,653	.5
4 years	Oct. 11, 1913	2	1.81	4.20	.74	8,287	14,917	8,684	15,631	.7
5 years	Oct. 8, 1914	2	1.83	6.01	.87	8,110	14,598	8,673	15,612	.8
¼-inch crushed coal—										
As stored	Sept. 12, 1909	2	1.78	5.67	.85	8,216	14,787	8,751	15,752	.....
After 3 months	Jan. 11, 1910	1	1.52	5.88	.79	8,188	14,739	8,742	15,736	.1
6 months	Apr. 7, 1910	2	1.28	6.02	.73	8,157	14,683	8,718	15,696	.4
9 months	July 13, 1910	2	1.54	5.71	.69	8,189	14,740	8,725	15,705	.3
1 year	Oct. 4, 1910	2	1.70	5.63	.64	8,208	14,774	8,736	15,724	.2
1½ years	Apr. 4, 1911	2	1.60	5.88	.69	8,160	14,687	8,708	15,674	.5
2 years	Oct. 4, 1911	2	1.54	6.04	.74	8,153	14,674	8,718	15,692	.4
3 years	Oct. 15, 1912	2	4.54	6.66	.88	8,041	14,473	8,661	15,590	1.0
4 years	Oct. 11, 1913	2	1.73	7.14	.82	7,986	14,375	8,647	15,565	1.2
5 years	Oct. 8, 1914	2	2.06	6.84	.82	8,011	14,420	8,646	15,562	1.2

[a] Gain.

TABLE 8.—*Storage tests of New River, W. Va., coal exposed to weather at Norfolk, Va., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.74	3.63	0.58	8,397	15,115	8,743	15,738	.....
After 3 months	Jan. 11, 1910	2	3.04	4.20	.74	8,345	15,021	8,745	15,741	0.0
6 months	Apr. 7, 1910	2	3.30	4.76	.65	8,283	14,909	8,732	15,717	.1
9 months	July 13, 1910	2	2.06	4.41	.59	8,336	15,004	8,752	15,754	[a].1
1 year	Oct. 4, 1910	2	2.06	5.19	.68	8,209	14,817	8,720	15,695	.3
1½ years	Apr. 4, 1911	2	9.90	5.05	.52	8,258	14,865	8,729	15,711	.2
2 years	Oct. 4, 1911	2	3.44	5.77	.65	8,157	14,683	8,695	15,650	.6
3 years	Oct. 15, 1912	2	6.80	5.41	.64	8,158	14,684	8,660	15,587	1.0
4 years	Oct. 11, 1913	2	6.25	4.60	.61	8,209	14,776	8,637	15,546	1.2
5 years	Oct. 8, 1914	2	6.59	6.19	.63	8,075	14,535	8,646	15,563	1.1
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	2.04	7.97	1.00	7,977	14,358	8,725	15,704	.....
After 3 months	Jan. 11, 1910	2	4.26	8.61	1.11	7,907	14,233	8,715	15,686	.1
6 months	Apr. 7, 1910	2	5.83	9.93	1.04	7,784	14,010	8,708	15,675	.2
9 months	July 13, 1910	2	1.48	8.45	.95	7,910	14,237	8,698	15,657	.3
1 year	Oct. 4, 1910	2	1.80	8.89	.93	7,843	14,118	8,666	15,598	.7
1½ years	Apr. 4, 1911	2	14.38	9.52	.91	7,785	14,013	8,664	15,594	.7
2 years	Oct. 4, 1911	2	5.38	10.84	.90	7,631	13,734	8,624	15,522	1.2
3 years	Oct. 15, 1912	2	13.48	10.83	.85	7,606	13,691	8,594	15,469	1.5
4 years	Oct. 11, 1913	2	11.92	12.49	.73	7,437	13,386	8,567	15,420	1.8
5 years	Oct. 8, 1914	2	15.72	10.62	.71	7,647	13,764	8,614	15,505	1.3

[a] Gain.

TABLE 9.—*Storage tests of New River, W. Va., coal submerged in fresh water at Pittsburgh, Pa., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.61	5.08	0.96	8,269	14,885	8,756	15,761	.....
After 3 months	Jan. 22, 1910	1	8.11	7.17	.95	8,072	14,530	8,748	15,746	0.1
6 months	Apr. 8, 1910	1	10.72	5.50	.76	8,230	14,814	8,752	15,754	.0
9 months	July 8, 1910	2	7.88	5.96	1.23	8,197	14,754	8,770	15,786	*a* .2
1 year	Oct. 7, 1910	2	8.97	6.11	1.15	8,175	14,715	8,762	15,771	*a* .1
1½ years	Apr. 13, 1911	2	9.65	5.18	1.04	8,256	14,860	8,751	15,751	.1
2 years	Oct. 9, 1911	2	12.09	7.36	.98	8,075	14,534	8,769	15,784	*a* .1
3 years	Oct. 4, 1912	2	7.32	5.60	1.24	8,170	14,706	8,707	15,672	.6
4 years	Oct. 7, 1913	2	8.96	5.89	1.01	8,184	14,730	8,743	15,737	.2
5 years	Oct. 15, 1914	2	10.83	9.30	2.41	7,844	14,119	8,749	15,747	.1
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	1.58	4.83	.64	8,299	14,939	8,752	15,754	.....
After 3 months	Jan. 22, 1910	1	18.04	5.28	.68	8,263	14,873	8,762	15,772	*a* .1
6 months	Apr. 8, 1910	1	23.62	5.47	.68	8,224	14,804	8,740	15,732	.1
9 months	July 8, 1910	2	19.64	5.18	.64	8,268	14,882	8,756	15,761	.0
1 year	Oct. 7, 1910	2	20.04	5.35	.61	8,245	14,841	8,747	15,744	.1
1½ years	Apr. 13, 1911	2	23.44	5.27	.64	8,248	14,847	8,743	15,738	.1
2 years	Oct. 9, 1911	2	19.78	5.69	.67	8,220	14,795	8,754	15,757	.0
3 years	Oct. 4, 1912	2	18.82	5.62	.75	8,163	14,693	8,663	15,639	.7
4 years	Oct. 7, 1913	1	20.26	5.84	.74	8,192	14,746	8,741	15,734	.1
5 years	Oct. 15, 1914	2	21.76	6.23	.80	8,160	14,687	8,745	15,741	.1

a Gain.

TABLE 10.—*Storage tests of New River, W. Va., coal exposed indoors at Pittsburgh, Pa., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.82	5.09	0.76	8,271	14,887	8,753	15,756	.....
After 3 months	Jan. 22, 1910	1	.89	3.91	.72	8,383	15,089	8,758	15,764	0.1
6 months	Apr. 8, 1910	2	.92	4.31	.89	8,301	14,942	8,715	15,687	.4
9 months	July 8, 1910	2	1.19	4.10	.71	8,360	15,047	8,750	15,749	.0
1 year	Oct. 7, 1910	2	1.43	4.63	.66	8,280	14,903	8,741	15,733	.1
1½ years	Apr. 13, 1911	2	.87	6.71	1.52	8,072	14,530	8,717	15,690	.4
2 years	Oct. 9, 1911	2	1.62	5.54	.74	8,216	14,789	8,737	15,727	.2
3 years	Oct. 4, 1912	2	1.80	3.60	.54	8,323	14,982	8,659	15,586	1.1
4 years	Oct. 7, 1913	2	1.83	4.40	.92	8,253	14,856	8,671	15,608	.9
5 years	Oct. 15, 1914	2	2.23	5.01	1.07	8,219	14,794	8,698	15,656	.6
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	1.68	6.08	1.04	8,189	14,740	8,769	15,787	.....
After 3 months	Jan. 22, 1910	1	2.72	6.69	1.19	8,103	14,585	8,740	15,732	.3
6 months	Apr. 8, 1910	2	.99	6.52	1.12	8,109	14,596	8,727	15,709	.5
9 months	July 8, 1910	2	1.39	6.12	1.01	8,152	14,673	8,733	15,719	.4
1 year	Oct. 7, 1910	2	1.48	6.68	.93	8,091	14,564	8,719	15,693	.6
1½ years	Apr. 13, 1911	2	1.08	6.64	1.11	8,068	14,523	8,695	15,650	.9
2 years	Oct. 9, 1911	2	4.14	8.83	1.03	7,888	14,198	8,714	15,685	.6
3 years	Oct. 4, 1912	2	2.99	10.27	1.20	7,678	13,820	8,626	15,527	1.6
4 years	Oct. 7, 1913	1	2.50	8.55	1.16	7,834	14,101	8,629	15,532	1.6
5 years	Oct. 15, 1914	2	2.81	9.25	1.20	7,763	13,974	8,620	15,515	1.7

TABLE 11.—*Storage tests of New River, W. Va., coal exposed to weather at Pittsburgh, Pa., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u
			P. ct.	*P. ct.*	*P. ct.*					*P. ct.*
Run-of-mine coal:										
As stored	Sept. 12, 1909	4	1.14	4.04	0.59	8,370	15,066	8,752	15,754	.....
After 3 months	Jan. 24, 1910	2	4.39	7.69	1.46	8,007	14,412	8,740	15,732	0.1
6 months	Apr. 22, 1910	2	2.35	6.21	.71	8,126	14,627	8,704	15,667	.6
9 months	July 12, 1910	2	1.49	4.24	.62	8,348	15,026	8,749	15,748	.0
1 year	Oct. 14, 1910	2	1.86	5.01	.70	8,245	14,841	8,716	15,689	.4
1½ years	Apr. 20, 1911	4	3.78	6.08	.89	8,136	14,646	8,708	15,674	.5
2 years	Oct. 12, 1911	2	4.85	8.28	.78	7,923	14,261	8,690	15,642	.7
3 years	Oct. 7, 1912	2	2.32	5.85	.89	8,096	14,573	8,642	15,555	1.3
4 years	Oct. 8, 1913	2	3.09	5.20	.61	8,178	14,721	8,661	15,589	1.0
5 years	Oct. 13, 1914	2	4.26	8.43	.62	7,877	14,179	8,650	15,570	1.2
¼-inch crushed coal:										
As stored	Sept. 12, 1909	4	1.29	7.45	.91	8,052	14,494	8,752	15,754	.....
After 3 months	Jan. 24, 1910	2	14.02	8.75	1.22	7,904	14,227	8,726	15,707	.3
6 months	Apr. 22, 1910	2	1.71	7.23	1.15	8,014	14,426	8,695	15,651	.7
9 months	July 12, 1910	2	1.22	7.79	1.05	7,971	14,348	8,701	15,662	.6
1 year	Oct. 14, 1910	2	1.99	8.33	1.06	7,918	14,253	8,697	15,655	.6
1½ years	Apr. 20, 1911	4	6.67	9.49	1.27	7,798	14,036	8,685	15,632	.8
2 years	Oct. 12, 1911	2	10.88	9.31	1.18	7,792	14,026	8,659	15,586	1.1
3 years	Oct. 7, 1912	2	2.92	8.75	.98	7,805	14,049	8,612	15,502	1.6
4 years	Oct. 8, 1913	2	6.36	8.60	.82	7,827	14,088	8,616	15,509	1.6
5 years	Oct. 13, 1914	1	11.67	7.19	.62	7,975	14,355	8,637	15,547	1.3

TABLE 12.—*Storage tests of New River, W. Va., coal, ¼-inch crushed, submerged in sea water at Key West (Dry Tortugas), Fla., in 50-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B.t.u.	Calories.	B.t.u.	Loss in B.t.u.
			P. ct.	*P. ct.*	*P. ct.*					*P. ct.*
Mine sample	Dec. 15, 1909	2	3.20	7.26	1.99	8,053	14,495	8,761	15,770	.....
As stored:										
Box 35	Jan. 29, 1910	2	.79	7.09	2.13	8,045	14,480	8,742	15,735	.....
36	do	2	1.02	6.55	.81	8,108	14,593	8,722	15,700	.....
37	do	2	.89	4.10	.82	8,362	15,052	8,755	15,759	.....
38	do	2	1.06	3.24	.81	8,434	15,180	8,747	15,745	.....
39	do	2	1.02	3.96	.74	8,388	15,099	8,766	15,779	.....
40	do	2	.92	5.21	.80	8,253	14,856	8,745	15,741	.....
41	do	2	.96	4.87	.89	8,282	14,908	8,746	15,743	.....
42	do	2	.97	4.41	.83	8,335	15,003	8,757	15,763	.....
43	do	2	.97	5.92	.95	8,180	14,723	8,739	15,730	.....
44	do	2	1.02	5.73	.90	8,193	14,747	8,734	15,721	.....
After 3 months:										
Box 35	Apr. 26, 1910	2	7.74	6.23	1.32	8,126	14,626	8,723	15,702	0.2
36	do	2	9.59	6.31	.82	8,116	14,638	8,706	15,671	.2
After 6 months:										
Box 35	July 14, 1910	2	17.84	6.70	1.46	8,088	14,559	8,731	15,716	.1
37	do	2	11.93	7.33	.88	8,027	14,449	8,712	15,681	.5
After 8 months:										
Box 35	Oct. 4, 1910	1	18.89	7.53	1.66	8,034	14,461	8,762	15,772	*a* .2
37	do	2	19.59	5.91	.91	8,163	14,694	8,720	15,695	.4
After 1 year:										
Box 35	Jan. 10, 1911	2	16.60	7.38	1.59	8,042	14,493	8,752	15,754	*a* .1
38	do	2	12.68	4.54	.88	8,281	14,906	8,714	15,685	.4
After 1½ years:										
Box 35	May 1, 1911	2	18.54	7.76	1.99	7,990	14,383	8,744	15,739	.0
39	do	2	14.97	4.48	.89	8,305	14,949	8,733	15,720	.4
After 1¾ years:										
Box 35	July 10, 1911	2	14.02	8.11	2.13	7,932	14,277	8,718	15,693	.3
40	do	2	18.78	6.68	.97	8,106	14,590	8,736	15,724	.1
After 2 years:										
Box 35	Jan. 10, 1912	2	12.64	8.72	2.57	7,882	14,187	8,734	15,721	.1
41	do	2	19.31	5.20	.86	8,275	14,895	8,770	15,786	*a* .3
After 2½ years:										
Box 35	July 8, 1912	2	13.69	8.50	2.73	7,872	14,169	8,706	15,671	.4
42	do	1	18.88	5.50	1.17	8,195	14,751	8,722	15,700	.4
After 3 years:										
Box 35	Feb. 1, 1913	2	17.85	7.88	2.38	7,895	14,210	8,661	15,589	.9
42	do	1	20.89	8.31	2.46	7,865	14,157	8,674	15,613	1.0
After 3¾ years:										
Box 43	Oct. 15, 1913	1	21.04	5.74	1.22	8,168	14,702	8,718	15,692	.2
44	do	2	10.00	7.20	1.24	8,011	14,420	8,692	15,645	.5

a Gain.

TABLE 13.—*Storage tests of New River, W. Va., coal exposed indoors at Key West (Dry Tortugas), Fla., in 350-pound portions.*[a]

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Jan. 29, 1910	2	0.91	8.29	2.15	7,935	14,283	8,741	15,734	.....
After 3 months	Apr. 26, 1910	2	1.19	11.18	3.11	7,642	13,756	8,733	15,720	0.1
6 months	July 14, 1910	1	1.26	10.27	3.54	7,697	13,855	8,712	15,682	.3
8 months	Oct. 4, 1910	2	1.14	11.67	5.45	7,539	13.570	8,731	15,715	.1
1 year	Jan. 10, 1911	1	1.83	10.79	4.30	7,628	13,730	8,710	15,678	.4
¼-inch crushed coal:										
As stored	Jan. 29, 1910	2	.75	7.15	2.33	8,068	14,523	8,777	15,799	.....
After 3 months	Apr. 26, 1910	2	2.99	7.40	2.15	8,051	14,492	8,778	15,800	.0
6 months	July 14, 1910	1	1.50	7.40	1.74	7,984	14,371	8,694	15,649	1.0
8 months	Oct. 4, 1910	2	1.83	7.82	1.84	7,952	14,314	8,703	15,666	.8
1 year	Jan. 10, 1911	1	2.12	7.84	1.94	7,922	15,052	8,676	15,617	1.2

[a] These test portions were transferred at the end of 1 year from indoor storage to outdoor.

TABLE 14.—*Storage tests of New River, W. Va., coal exposed to weather at Key West (Dry Tortugas), Fla., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
Lot A—As stored	Jan. 29, 1910	2	0.80	11.03	3.38	7,668	13,803	8,754	15,757	.....
Lot B—As stored	do	2	.91	8.29	2.15	7,935	14,283	8,741	15,734	.....
Lot A—										
After 3 months	Apr. 26, 1910	2	1.30	8.85	2.60	7,843	14,118	8,706	15,671	0.5
6 months	July 14, 1910	1	2.05	9.29	1.74	7,822	14,080	8,706	15,671	.5
8 months	Oct. 4, 1910	2	1.73	4.94	1.62	8,165	14,696	8,703	15,666	.6
1 year	Jan. 10, 1911	1	1.91	5.91	2.07	8,137	14,647	8,722	15,700	.4
Lot B—										
After 1½ years	May 1, 1911	2	1.61	9.62	3.18	7,742	13,936	8,688	15,638	.6
1½ years	July 10, 1911	1	1.74	7.49	2.07	7,943	14,297	8,670	15,606	.8
2 years	Jan. 10, 1912	1	2.06	7.37	1.33	7,937	14,287	8,632	15,538	1.2
2½ years	July 8, 1912	1	1.08	7.20	1.64	7,916	14,249	8,598	15,476	1.6
3 years	Feb. 1, 1913	1	1.79	9.99	1.70	7,679	13,822	8,513	15,323	2.6
¼-inch crushed coal:										
Lot A—As stored	Jan 29, 1910	2	1.08	4.00	.73	8,362	15,052	8,745	15,740	.....
Lot B—As stored	do	2	.75	7.15	2.33	8,068	14,523	8,777	15,799	.....
Lot A—										
After 3 months	Apr. 26, 1910	2	2.28	5.57	1.11	8,189	14,741	8,721	15,698	.3
6 months	July 14, 1910	1	1.27	5.59	1.14	8,172	14,710	8,706	15,671	.4
8 months	Oct. 4, 1910	2	1.80	5.70	1.05	8,150	14,670	8,690	15,642	.6
1 year	Jan. 10, 1911	1	3.16	7.97	1.17	7,933	14,279	8,680	15,624	.7
Lot B—										
After 1½ years	May 1, 1911	2	1.38	6.69	1.65	8,038	14,468	8,681	15,625	1.1
1½ years	July 10, 1911	1	1.33	6.58	1.83	7,983	14,369	8,618	15,512	1.8
2 years	Jan. 10, 1912	1	4.27	6.87	1.65	7,941	14,294	8,592	15,466	2.1
2½ years	July 8, 1912	1	1.19	6.71	1.90	7,907	14,233	8,547	15,385	2.6
3 years	Feb. 1, 1913	1	12.96	7.88	1.67	7,817	14,071	8,557	15,403	2.5

TABLE 15.—*General summary of tests of New River coal.*

Condition of test.	Percentage loss in heat value during—								
	3 months.	6 months.	9 months.	1 year.	1½ years.	2 years.	3 years.	4 years.	5 years.
Submerged:									
Portsmouth, N. H.	0.2	0.5	0.1	0.0	0.5	0.3	1.1	0.5	0.4
Norfolk, Va.	.3	.2	.1	.2	.2	.5	.9	.4	.5
Key West, Fla.	.2	.3	.1	.2	.2	.0	.9	.4	.....
Pittsburgh, Pa.—									
Run-of-mine coal	.1	.0	.0	.0	.1	.0	.6	.2	.1
¼-inch crushed coal	.0	.1	.0	.1	.1	.0	.7	.1	.1
Average	.16	.55	.06	.10	.55	.16	.84	.32	.28
Exposed indoors:									
Run-of-mine coal—									
Portsmouth, N. H.	.0	.....	.....	.1	.5	.3	.9	.8	1.0
Norfolk, Va.	.0	.1	.1	.2	.2	.2	.5	.7	.8
Key West, Fla.	.1	.3	.1	.4	.....	.....	.....	.....	.....
Pittsburgh, Pa.	.1	.4	.0	.1	.4	.2	1.1	.9	.6
¼-inch crushed coal—									
Portsmouth, N. H.	.6	.....	.....	.4	.7	.9	1.3	1.6	1.4
Norfolk, Va.	.1	.4	.3	.2	.5	.4	1.0	1.2	1.2
Key West, Fla.	.0	1.0	.8	1.2	.....	.....	.....	.....	.....
Pittsburgh, Pa.	.3	.5	.4	.6	.9	.6	1.6	1.6	1.7
Weathered:									
Run-of-mine coal—									
Portsmouth, N. H.	.2	.4	.4	.2	.4	.7	1.1	1.0	1.4
Norfolk, Va.	.0	.1	.0	.3	.2	.6	1.0	1.2	1.1
Key West, Fla.	.5	.5	.6	.4	.8	1.2	2.6	.....	.....
Pittsburgh, Pa.	.1	.6	.0	.4	.5	.7	1.3	1.0	1.2
¼-inch crushed coal—									
Portsmouth, N. H.	.3	.3	.3	.5	.7	.9	1.3	1.2	1.3
Norfolk, Va.	.1	.2	.3	.7	.7	1.2	1.5	1.8	1.3
Key West, Fla.	.3	.4	.6	.7	1.8	2.1	2.5	.....	.....
Pittsburgh, Pa.	.3	.7	.6	.6	.8	1.1	1.6	1.6	1.3

TABLE 16.—*Results of storage tests of New River coal showing ultimate composition of "unit" coal substance, and changes during storage.*

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Total sulphur.	Sulphate sulphur.
Mine sample 1, Aug. 27, 1909	89.86	4.87	1.51	3.76	0.83	0.005
Mine sample 2, Dec. 14, 1909	89.70	4.89	1.66	3.75	2.18	.....
Portsmouth, N. H.:						
As stored under water	89.52	4.89	1.52	4.07	1.06	.006
Submerged—						
2 years	89.71	4.68	1.74	3.87	1.04	.030
5 years	89.00	4.84	1.72	4.44	1.36	.....
As stored, exposed outdoors	89.82	4.86	1.57	3.75	1.24	.004
Exposed outdoors—						
3 months	89.86	4.70	1.54	3.90	1.38	.020
6 months	90.11	4.91	1.63	3.35	1.29	.038
1 year	89.91	4.62	1.58	3.89	1.18	.....
2 years	89.56	4.77	1.75	3.92	.98	.105
5 years	89.52	4.85	1.67	3.96	.78	.....
Exposed indoors 5 years	89.42	4.78	1.71	4.09	1.05	.....
Key West, Fla.:						
As stored under water	89.80	4.79	1.75	3.66	2.63	.011
Submerged—						
8 months	89.73	4.76	1.68	3.83	2.01	.....
2 years	90.39	4.83	1.59	3.19	2.96	.....
As stored, exposed outdoors	90.61	4.87	1.67	2.85	.79	.007
Exposed outdoors—						
8 months	89.68	4.70	1.62	4.00	1.29	.....
2 years	88.13	4.87	1.83	5.17	2.07	.25
Pittsburgh, Pa.:						
As stored under water	89.99	5.00	1.59	3.42	.71	.006
Submerged—						
3 months	90.18	4.79	1.64	3.39	.73	.000
6 months	90.26	4.85	1.63	3.26	.77	.005
1 year	90.15	4.68	1.68	3.49	.75	.....
As stored, exposed indoors	89.59	4.86	1.55	4.00	1.25	.005
Exposed indoors—						
3 months	89.93	4.79	1.66	3.62	1.23	.020
6 months	89.36	5.17	1.65	3.82	1.38	.022
1 year	90.08	4.67	1.63	3.62	1.26	.....
2 years	90.31	4.74	1.70	3.25	1.10	.043
Exposed outdoors, 5 years	90.23	4.75	1.74	3.28	.76	.08

DISCUSSION OF RESULTS OF TESTS.

The tables show that the maximum deterioration in heating value in one year was 1.2 per cent in one-fourth inch coal exposed indoors at Key West (Dry Tortugas); and the maximum in two years was 2.1 per cent in the same portion after a second year out of doors. The warmer climates of Norfolk and Key West (Dry Tortugas) caused uniformly greater deterioration in the exposed coal than the cooler ones of Pittsburgh and Portsmouth. The one-fourth inch coal showed losses almost always 50 to 100 per cent greater than those of the run-of-mine.

After one year the submerged coal in six out of eight portions at the different storage points showed no loss of heat value. Two portions had lost about 0.4 per cent. After two years' submergence, three out of eight portions showed losses ranging from 0.4 to 0.6 per cent, the remainder being less than 0.2 per cent, and after five years the loss in two portions was practically nothing, the other two tested showing losses of 0.4 and 0.5 per cent.

Slight, continuous decreases in heating value were noted after the two-year period in the exposed coal, the maximum being 2.6 per cent at Key West (Dry Tortugas). In five years the maximum loss at Portsmouth was 1.4 per cent, at Pittsburgh 1.7 per cent, and at Norfolk 1.3 per cent.

It should be noted that the probable experimental accuracy in the determination of calorific value by the method used was not more than 0.2 per cent, and that, including the effect of the errors in determination of moisture, ash, and sulphur, in computing the "unit coal" value, a possible deviation of 0.4 per cent might occur between the values obtained for duplicate samples of the same portion. The losses indicated, therefore, in the submergence tests are almost within the experimental error, and may be said to have been inconsiderable. The tests of coal in box 10 at Norfolk appear to show that alternate drying in the open air for brief intervals between the submergence periods causes some loss, although not a material one.

The variation in ultimate composition of the coal substance as shown in Table 16 was very slight, if any. The probable experimental error in these analyses is 0.25 per cent for carbon, 0.03 per cent for hydrogen, 0.02 per cent for nitrogen, and 0.20 per cent for moisture and ash, throwing an aggregate probable error on the oxygen (determined by difference) of 0.50 per cent, or a possible variation between duplicates of 1 per cent. Any indications of change in percentage of oxygen in the coal during storage are, therefore, within the experimental error, and the only conclusion justifiable is that the change in oxygen content, if any, appears to be of the same order of magnitude as the change in calorific value.

No actual determination of the amount of physical deterioration of lumps was made, but by observation of the run-of-mine coal stored outdoors at Pittsburgh it was noted that very little slacking or weakening of the lumps occurred during two years. This is illustrated in Plate IV, *A*, which shows the condition of the run-of-mine coal after two years' exposure. Plate IV, *B*, shows crushed coal after two years' exposure under similar conditions.

CONCLUSION.

In general, the conclusion to be drawn from these tests is that New River coal, under severe conditions of outdoor exposure to the weather, deteriorates in heating value approximately 1 per cent in the first year, 2 per cent in the first two years, and not over 3 per cent in five years. Storage under water prevents practically all deterioration during one year, and no more than 0.5 per cent has been found in any test for two years or less. Salt water possesses no advantage over fresh water in preventing deterioration. Intermittent exposure and partial drying of the submerged coal probably causes deterioration in some degree, although very small.

Submergence storage of New River coal is not to be recommended for the sake of preventing deterioration in heat value. Its advantage lies only in insuring against spontaneous combustion.

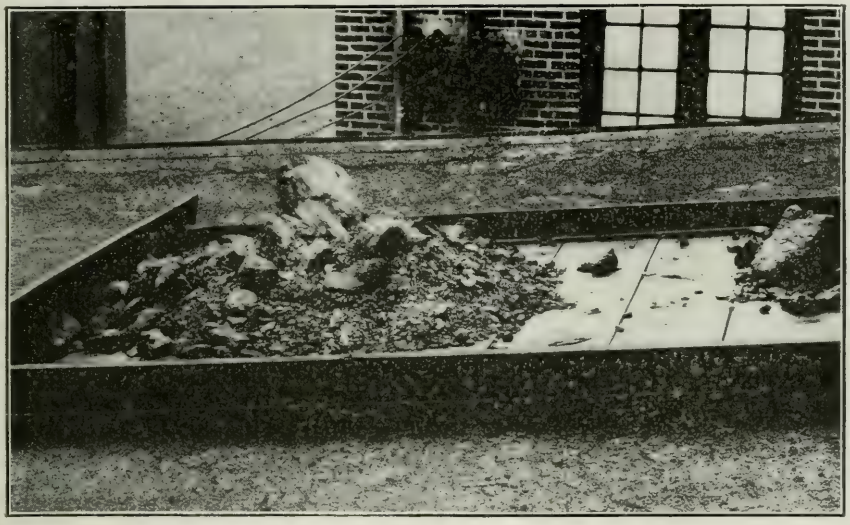
TESTS OF PITTSBURGH GAS COAL AT ANN ARBOR, MICH.

Experiments to determine the loss in heating value of coal of the Pittsburgh bed and its deterioration for purposes of illuminating-gas manufacture, during periods of storage ranging from six months to five years, were begun in November, 1910, at Ann Arbor, Mich., in cooperation with the Michigan Gas Association and the University of Michigan. The periodic sampling of the coal for determination of its heating value was done under the direction of Prof. A. H. White, of the university, who also carried out the tests of the coal for yields of gas and by-products. The results of the gas tests are to be reported by Prof. White.

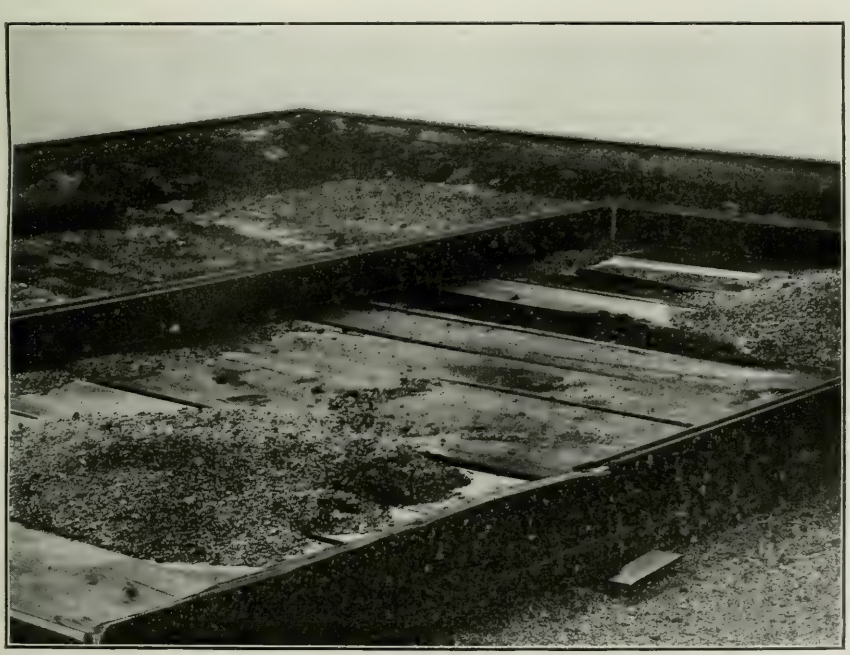
Coal was obtained for the tests from two different mines, both working the Pittsburgh bed and producing coal commonly used in gas manufacture.

SOURCE OF THE COAL.

The coal designated in the tests "AA15" was mined November 1, 1910, at the Schoenberger mine at Baird Station, Washington County, Pa. It consisted of a small carload (21½ tons, net weight) of lump coal screened over a three-fourths-inch bar screen, and was loaded and sampled under the supervision of one of the mining engineers of the bureau. Mine samples were taken at six different points in the mine and a



A. RUN-OF-MINE NEW RIVER COAL AFTER TWO YEARS' WEATHERING AT PITTSBURGH, PA. (SHOWING LUMPS INTACT).



B. FINELY CRUSHED NEW RIVER COAL AFTER TWO YEARS' WEATHERING AT PITTSBURGH, PA.

composite of these made for analysis. The car arrived at Ann Arbor November 12, 1910, and was unloaded into the bins November 15 and 16, a gross sample of 3 to 4 tons representing the car being set aside at that time. On November 18 and 19 this gross sample was reduced to two 300-pound lots as described in page 24, and on November 23 these were further reduced for analysis to two laboratory samples of 2½ to 3 pounds each.

The coal designated "AA16" was mined December 9, 1910, at Consolidation No. 63 mine at Monongah, Marion County, W. Va. It was a small carload (29½ tons, net weight) of coal screened over a three-fourths-inch bar screen, loaded and sampled under the supervision of a mining engineer of the bureau. Mine samples were taken at four different points in the mine and a composite of these made for analysis. The car arrived at Ann Arbor December 28, 1910, and was unloaded into the bins December 30 and 31. A gross sample of 3 or 4 tons was removed during the unloading and reduced at that time, as described elsewhere (p. 24), to two 300-pound lots. On January 6, 1911, these were crushed and reduced further to laboratory samples.

TESTS IN OPEN BINS.

The bins were located at the works of the Ann Arbor Gas Co. in the open yard adjoining the retort house. The coal in the bins was exposed to the weather, the bins being so constructed that the conditions in an ordinary coal pile 10 feet deep were approximately simulated. Each of the two bins covered a floor space 11½ by 7½ feet, was 10 feet high, and was divided by board partitions into six compartments. Each compartment was 7½ feet long, 10 feet high, and 20 inches wide, held about 3 tons of coal at 7 feet depth and 4 tons at 9½ feet depth. The bins were backed up against a concrete wall, had a board floor, and were uncovered except for a screen of poultry netting.

At the end of each successive period one of the six compartments was emptied and the coal tested, both for heating value and for gas-making qualities.

TESTS OF STORAGE BY SUBMERGENCE UNDER WATER.

Four barrels, each holding 300 to 320 pounds, were filled, two with each kind of coal. Both ends of each barrel were perforated with about 10 ¾-inch holes to allow escape of air and complete filling with water when submerged.

The barrels of coal "AA15," numbered 1 and 2, were filled with coal (part of the 3 or 4 ton gross sample above referred to) on January 7, 1911, and were submerged January 14, 1911; those of coal "AA16," numbered 3 and 4, were filled January 9 and submerged January 14.

The barrels were lowered under the water of a supply basin (see Pl. V, *A*, p. 32) 6 or 8 feet deep, near the gas works, the water of of which is kept fresh constantly by springs and does not freeze.

One of the barrels of each kind of coal remained submerged continuously until the expiration of 5½ years of storage. The other was raised after the expiration of 6 months, 1½ years, 2½ years, 3½ years, and 4½ years, sampled each time, and returned to the water.

METHODS OF PREPARING AND SAMPLING COAL.

The cars of coal were unloaded by hand, single shovelfuls being thrown in rotation into each of the six bins and into a chute leading to an inclosed sampling floor. The carload was thus divided into seven equal representative portions. The portion on the sampling floor, 3 or 4 tons, was, without further preparation, divided into four equal portions, three of these being sacked for gas tests, and the fourth reserved for sampling. By alternate shovelfuls this last quarter was divided into two duplicate portions of 800 to 1,000 pounds each, and these in turn were each divided into five equal portions. Of these five portions, of 160 to 200 pounds each, one served for a special "change of weight" test in an open ash-can, two of the others made up the barreled lot for submergence, and the last two portions, aggregating 300 to 400 pounds, served for reducing down to laboratory samples. This was done by crushing the coal and quartering it in the usual manner by spreading out and rejecting opposite quarters. After each reduction of quantity the coal was crushed to a smaller size.

TESTS TO DETERMINE CHANGE IN WEIGHT DURING STORAGE.

In order to determine the change in weight of the dry coal substance by oxidation or other weathering effect, during storage, two weighed portions of each coal of about 200 pounds each were placed in galvanized-iron ash cans, without covers, and exposed to outdoor conditions. The bottoms of these cans were perforated to allow water to drain out, the coal resting on two thicknesses of 16-mesh wire screening so as to reduce mechanical losses to a minimum. Similar screening covered the tops of the cans. After standing indoors for two or three weeks, to become air-dried, the cans were weighed and then buried to half their depth in the coal of the test bins. After stated periods of exposure the cans were air dried, weighed, sampled, again weighed, and returned to the bins. By computing from the analysis and weight the dry coal substance present, any change of weight due to weathering was determined. The weighings were made with an accuracy of 0.5 pound or about 0.2 per cent.

The results of these tests indicate little, if any, change of weight within the error of measurement of the dry coal substance in five years' exposure. Table 17 shows the actual weights.

TABLE 17.—*Change in weight of Pittsburgh gas coal during five years' exposure.*

Item.	Coal AA15, from Baird Station, Pa. (can 2).		Coal AA16, from Monongah, W. Va. (can 4).	
	As stored.	After five years.	As stored.	After five years.
Gross weight, pounds	239.0	238.5	237.5	235.0
Weight of can, pounds	30.5	30.5	30.0	30.0
Net weight of coal, pounds	208.5	208.0	207.5	205.5
Moisture in coal, per cent	2.2	1.6	2.9	1.7
Weight of dry coal, pounds	203.9	204.7	201.5	202.0
Change in dry weight, per cent	.....	+0.4	.....	+0.3

The recorded weights of cans 1 and 3, taken at intervals during the five years' period, are incomplete and have been omitted from the table, because, unfortunately, a record was not preserved in every instance of the weights both before and after sampling so as to show how much coal was lost in sampling. The final change in weight of these portions therefore represents both the loss in sampling and the change due to weathering, and the latter is indeterminate.

The results showing deterioration in heating value of the two coals, both in the open bins and in the submergence tests, are given in Tables 18 and 19. It is to be noted, as was explained in connection with the tests of New River coal, that the only fair basis for comparing analyses in determining deterioration is the dry coal substance, free of sulphur and ash.

On this basis the amount of deterioration in one year's open air storage was practically negligible, even in the upper six inches of the exposed coal. During the second, third, fourth, and fifth years the deterioration proceeded very slowly and did not reach an amount greater than 1.1 per cent in five years. The submerged portions may be said to have suffered practically no loss measureable by the degree of accuracy used.

TABLE 18.—*Storage tests of screened lump (over ¾-inch) coal from the Pittsburgh bed at Baird Station, Pa., exposed to weather at Ann Arbor, Mich., in 3-ton lots.*

Weight under test.	Method of storing.	Sample from—	Date of sampling.	Duration of storage.	Number of samples averaged.	Moisture.	Analysis on dry basis.					Heating value of "unit coal."		
							Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B. t. u.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*					*Per ct.*
		Mine	Nov. 3, 1910			3.94	34.93	59.14	5.93	1.08	7,991	14,384	8,545	15,381	
		Car during loading.	Nov. 1, 1910		4	2.44			6.30	.87	7,968	14,343	8,549	15,388	
		Car during unloading.	Nov. 23, 1910		2	2.23			6.34	.89	7,959	14,325	8,541	15,374	
3 tons	Open bin	Entire bin	June 8, 1911	6 months	2	2.41			8.29	.90	7,782	14,008	8,539	15,370	0.0
Do	do	Surface of bin	do	do	1	2.00			7.13	.95	7,895	14,211	8,551	15,392	*a*.1
Do	do	Entire bin	Dec. 4, 1911	1 year	2	6.34			8.47	.96	7,752	13,954	8,526	15,347	.2
Do	do	Surface of bin	do	do	1	8.59			8.16	1.05	7,782	14,008	8,528	15,350	.2
Do	do	Entire bin	Dec. 19, 1912	2 years	2	2.38	34.27	58.14	7.60	1.07	7,777	13,998	8,471	15,248	.8
Do	do	Surface of bin	do	do	1	2.13	34.09	58.73	7.18	1.07	7,817	14,071	8,474	15,253	.8
Do	do	Entire bin	Nov. 3, 1913	3 years	2	3.80	34.55	57.22	8.24	1.02	7,727	13,908	8,477	15,259	.7
Do	do	Surface of bin	Oct. 31, 1913	do	1	2.63	36.85	54.51	8.64	.75	7,716	13,889	8,497	15,295	.5
Do	do	Entire bin	Dec. 11, 1914	4 years	1	2.72	35.84	57.90	6.26	1.03	7,916	14,249	8,493	15,287	.6
Do	do	Surface of bin	do	do	1	2.45	35.49	57.60	6.91	1.08	7,857	14,143	8,492	15,286	.6
Do	do	Entire bin	Jan. 29, 1916	5 years	1	1.88	35.36	58.09	6.55	1.12	7,876	14,177	8,479	15,262	.7
Do	do	Surface of bin	do	do	1	1.55	35.46	58.27	6.27	1.01	7,902	14,224	8,477	15,259	.7
300 pounds	Submerged	Barrel 1	Jan. 7, 1911	As stored	2	2.09			5.82	.82	7,998	14,396	8,533	15,359	
Do	do	do	June 15, 1911	6 months	1	1.21			5.84	.97	8,015	14,427	8,557	15,403	*a*.3
Do	do	do	May 29, 1912	1½ years	2	4.42	35.23	58.09	6.69	1.13	7,885	14,192	8,501	15,302	.4
Do	do	do	June 9, 1913	2½ years	1	6.04	35.74	57.01	7.25	1.29	7,828	14,090	8,499	15,298	.4
Do	do	do	June 8, 1914	3½ years	1	3.72	36.64	56.97	6.39	1.12	7,947	14,305	8,540	15,372	*a*.1
Do	do	do	May 19, 1915	4½ years	1	2.47	35.12	55.95	8.93	1.06	7,740	13,932	8,559	15,406	*a*.3
Do	do	Barrel 2	do	do	1	2.47	36.31	57.17	6.52	1.31	7,919	14,254	8,527	15,349	.1

a Gain.

TABLE 19.—*Storage tests of screened lump (over ¾-inch) coal from the Pittsburgh bed at Monongah, W. Va., exposed to the weather at Ann Arbor, Mich.; in 4-ton lots.*

Weight under test.	Method of storing.	Sample from—	Date of sampling.	Duration of storage.	Number of samples averaged.	Moisture.	Analysis on dry basis.						Heating value of "unit coal."		
							Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B. t. u.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*					*Per ct.*
		Mine	Dec. 10, 1910			2.95	36.07	58.16	5.77	0.69	7,935	14,283	8,458	15,224	.....
		Car during loading	....do		4	2.35			7.78	.68	7,806	14,050	8,509	15,316	.....
		Car during unloading.	Jan. 6, 1911		2	2.91			9.04	.68	7,681	13,827	8,514	15,325	.....
4 tons	Open bin	Entire bin	June 8, 1911	6 months	2	2.22			8.85	.74	7,726	13,907	8,528	15,350	a 0.2
Do	....do	Surface of bin	....do	....do	1	2.16			8.90	.56	7,711	13,880	8,513	15,323	.0
Do	....do	Entire bin	Dec. 16, 1911	1 year	2	3.19			9.24	.78	7,680	13,823	8,516	15,329	.0
Do	....do	Surface of bin	....do	....do	1	4.56			9.19	.82	7,674	13,814	8,507	15,313	.1
Do	....do	Entire bin	Dec. 19, 1912	2 years	2	2.40	35.77	54.56	9.68	.88	7,593	13,667	8,465	15,237	.6
Do	....do	Surface of bin	....do	....do	1	2.81	36.33	55.88	7.79	.77	7,742	13,936	8,443	15,197	.8
Do	....do	Entire bin	Nov. 3, 1913	3 years	2	3.45	36.58	55.72	7.70	.72	7,770	13,986	8,464	15,235	.6
Do	....do	Surface of bin	....do	....do	1	2.46	35.04	56.80	8.16	1.12	7,763	13,973	8,511	15,320	.0
Do	....do	Entire bin	Dec. 11, 1914	4 years	1	2.41	36.85	55.61	7.54	.81	7,785	14,013	8,467	15,241	.5
Do	....do	Surface of bin	....do	....do	1	3.26	37.28	55.80	6.92	.70	7,841	14,114	8,466	15,239	.6
Do	....do	Entire bin	Jan. 29, 1916	5 years	1	1.93	37.06	55.83	7.11	.75	7,812	14,062	8,455	15,219	.7
Do	....do	Surface of bin	....do	....do	1	1.73	37.47	54.88	7.65	.63	7,732	13,918	8,416	15,149	1.1
300 pounds	Submerged	Barrel 3	Jan. 9, 1911	As stored	2	2.81			9.10	.72	7,666	13,799	8,506	15,311	.....
Do	....do	....do	June 15, 1911	6 months	1	1.41			8.23	.69	7,776	13,996	8,521	15,338	a .2
Do	....do	....do	May 29, 1912	1½ years	1	3.00	36.54	55.74	7.72	.75	7,754	13,957	8,453	15,215	.6
Do	....do	....do	June 9, 1913	2½ years	1	4.75	37.89	54.75	7.36	.87	7,810	14,058	8,479	15,262	.3
Do	....do	....do	June 8, 1914	3½ years	1	3.25	37.33	52.83	9.84	.98	7,630	13,734	8,524	15,343	a .2
Do	....do	....do	May 19, 1915	4½ years	1	2.16	38.01	52.75	9.24	.83	7,683	13,829	8,521	15,338	a .2
		Barrel 4	....do	....do	1	2.69	37.71	53.63	8.66	.81	7,692	13,846	8,474	15,253	.4

a Gain.

TABLE 20.—*Ultimate composition of coals from the Pittsburgh bed, on basis of ash and moisture free substance, after various periods of storage at Ann Arbor, Mich.*

	"AA15" coal from Baird, Pa.					"AA16" coal from Monongah, W. Va.				
	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Sulphur.	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Sulphur.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Mine sample (composite)	85.44	5.41	1.52	6.48	1.15	85.17	5.47	1.51	7.12	0.73
Car sample, as unloaded	85.09	5.32	1.65	6.79	1.15	84.84	5.67	1.68	6.88	.93
Coal in open bins after 4 years' weathering	84.91	5.47	1.61	6.91	1.10	85.01	5.62	1.74	6.75	.88
Coal in open bins after 5 years' weathering	85.27	5.56	1.70	6.27	1.20	84.86	5.61	1.68	7.04	.81
Same, 6-inch surface layer	84.94	5.46	1.71	6.81	1.08	84.95	5.74	1.75	6.88	.68
Coal, as submerged for test	85.35	5.54	1.68	6.41	1.02	84.35	5.49	1.63	7.57	.96
Same after 4½ years' storage, submerged	85.61	5.64	1.66	5.69	1.40	84.84	5.68	1.73	6.86	.89

TESTS OF POCAHONTAS COAL MADE ON THE ISTHMUS OF PANAMA.

During the year ended June 1, 1910, a large number of samples were taken of Pocahontas (Va.) coal as unloaded on one part of the general stock pile of the Panama Railroad Co. at dock No. 14, Cristobal, Isthmus of Panama. These samples were analyzed in order to determine the average heating value of the coal, as placed on the pile, for comparison with the heating value of the same coal as determined on removal from the pile after different periods of storage. Some time previous to June 1, 1910, when the fact was discovered by the Bureau of Mines, this part of the stock pile was several times almost entirely dug up and consumed, and no samples of the coal were taken. The analyses made up to that time became, therefore, useless for any test of deterioration, and a new series of tests was begun.

On June 16, 1910, a small test pile of 120 tons of Pocahontas run-of-mine was established near dock No. 14, separate from the general stock pile. The coal was the cargo of the steamship *Vauxhall*, leaving Norfolk, Va., June 1, and unloaded at Cristobal June 13 to 18. One average sample of the coal as placed on the pile was sent to the bureau for analysis, but no report was made to the bureau of the exact method of taking the sample. Every three months after the test pile was established a 10-ton portion (consisting of an entire vertical section across the shorter dimension of the pile) was removed and thoroughly sampled. Eight samples were taken each time, by throwing aside 400 to 800 pounds into each of four boxes, in small portions at regular intervals as the 10 tons were removed; these 400-pound portions were then crushed and reduced by quartering, two small can samples being taken from each.

A summary of the results follows:

TABLE 21.—*Storage test of Pocahontas (Va.) coal.*

[120 tons in open pile, near dock No. 14, Cristobal, Isthmus of Panama.]

Item.	Original as stored, June 16, 1910 (sample).	After 3 months' storage, Sept. 21, 1910 (average of 7 samples).	After 6 months' storage, Dec. 18, 1910 (average of 8 samples).	After 9 months' storage, Mar. 20, 1911 (average of 8 samples).	After 13 months' storage, July 18, 1911 (average of 8 samples).	After 2 years' storage, June 15, 1912 (average of 2 samples).
Air-drying loss	.....	4.37	6.28	3.89	4.21	5.55
Coal, as received:						
Moisture	0.94	4.96	6.72	4.47	5.34	6.79
Ash	5.51	6.76	6.66	5.53	6.20	6.56
Sulphur	.73	.49	.52	.59	.48	.57
Calories	8,188	7,721	7,625	7,764	7,716	7,508
British thermal units	14,738	13,898	13,725	13,975	13,889	13,515
Coal, free of moisture, sulphur and ash (calculated):						
Calories	[a]8,794	8,786	8,761	8,766	8,762	8,723
British thermal units	15,829	15,815	15,770	15,779	15,772	15,701
Percentage of loss (in B. t. u.) during storage	.....	0.09	0.38	0.32	0.37	0.81

[a] For a check on this analysis of coal as stored, the analyses of 14 samples taken from the same cargo when loaded at Norfolk, June 1, 1910, show on the moisture, sulphur, and ash-free basis an average calorific value of 8,790 calories.

As explained under the report on New River coal, the only fair basis of comparison in studying deterioration of heating value is the coal substance free of its accidental impurities—moisture, sulphur, and ash.

On this basis, therefore, and on the basis of average samples of the entire cross-section of the pile, the results given in Table 21 show that during one year's outdoor exposure this coal deteriorated very slightly (less than 0.4 per cent) in heating value, and that the deterioration took place entirely during the first six months (June 15 to Dec. 15). There was a further deterioration of 0.4 per cent during the second year.

The climatic conditions during the period of storage are indicated by the following table:

TABLE 22.—*Monthly temperature averages and precipitation at Colon, R. P., June 1, 1910, to June 1, 1912.*

	Temperature of air.			Average temperature of sea water.	Total precipitation.
	Average mean.	Average maximum.	Highest.		
1910.	° F.	° F.	° F.	° F.	*Inches.*
June	79.4	83.9	89	83.1	13.63
July	77.6	82.1	86	82.5	21.07
August	78.4	82.5	86	83.2	14.93
September	78.6	84.0	88	83.6	12.05
October	78.5	84.4	89	82.5	15.65
November	77.8	82.1	88	80.6	30.04
December	77.3	80.5	82	79.8	15.20
1911.					
January	78.4	81.4	82	80.2	0.99
February	77.9	81.1	82	80.3	1.81
March	78.3	81.5	82	80.3	1.41

TABLE 22.—*Monthly temperature averages and precipitation at Colon, R. P., June 1, 1910, to June 1, 1912*—Continued.

	Temperature of air.			Average temperature of sea water.	Total precipitation.
	Average mean.	Average maximum.	Highest.		
1911.	° F.	° F.	° F.	° F.	*Inches.*
April	79.6	82.8	84	81.6	3.06
May	79.5	84.8	88	82.6	17.13
June	79.3	83.7	88	82.4	16.58
July	81.1	84.4	86	84.0	14.58
August	79.7	83.6	86	84.1	11.60
September	80.6	84.7	90	84.8	11.62
October	79.4	83.6	90	81.6	16.53
November	79.4	84.3	89	81.9	15.81
December	82.0	86.4	89	81.7	2.63
1912.					
January	82.1	86.4	88	80.9	0.28
February	80.8	84.7	88	80.7	1.81
March	82.5	86.8	88	81.1	0.66
April	82.8	87.7	90	82.8	0.75
May	82.0	86.6	91	83.4	12.03

TESTS OF SHERIDAN (WYO.) SUBBITUMINOUS COAL.

About December 30, 1907, five wooden bins, constructed by the Chicago, Burlington & Quincy Railway Co. in the railroad yards at Sheridan, Wyo., were filled with coal from the Dietz mines near Sheridan. The bins adjoined one another in the same structure, the side walls of each serving as partitions. They were built of heavy matched lumber, but allowed more or less circulation of air through cracks. One bin was left without roof, and the coal thus fully exposed to the weather, but the other four were roofed over.

Bin 1, 4 feet wide, 8 feet high, with open top and end, contained about 4 tons of run-of-mine coal piled about 5 feet deep.

Bin 2 was a duplicate of bin 1, except that top and ends were closed.

Bin 3, of the same size as bins 1 and 2, with closed top and ends, contained about 4 tons of run-of-mine coal, moistened with about 7 per cent of added water.

Bin 4, 4 feet wide, 18 feet high, with closed top and ends, contained 10 to 12 tons of run-of-mine coal, piled about 15 feet deep.

Bin 5 was a duplicate of bin 4, except that slack coal (through 3-inch mesh screens) was used instead of run of mine.

Bins 1, 2, 3, and 4 were loaded with run-of-mine coal from one carload, and three samples were taken from the car as it was unloaded. Small portions were thrown aside at regular intervals during the unloading, and the three gross samples thus obtained were crushed to one-half-inch size and quartered down. Bin 5 was filled from a car of the commercial output of slack coal (3-inch screenings), and one sample was taken by the method just described.

All sampling after that at the start of the tests and prior to that at the expiration of two and three-fourths years was done by the so-

called "grab" method, so as not to disturb the entire lot, and thus expose its under portions to undue weathering. A spot 2 by 3 feet square was dug away for about 1 foot in depth and several small, well-distributed portions removed therefrom. These were combined, crushed, mixed, and quartered to the laboratory size.

The sampling carried out October 1, 1910, after a two and three-fourths years' period, was done by rehandling the entire amount in each bin. The coal was transferred to a temporary bin, and during the transfer an average sample was taken by the method used when loading the bins. The coal was then returned to its proper bin.

The samples were mailed to the Pittsburgh laboratory in sealed metal cans and there analyzed. The "unit coal" basis, as previously explained (p. 12), was used in all comparisons of calorific values.

It was impracticable in these tests to determine accurately the change in weight of the actual fuel substance of the coal, and in fact an element of uncertainty due to the same cause enters into practically all tests of deterioration of the coal. Laboratory experiments have shown that coal ordinarily increases slightly in weight on exposure to the air, if the measurement be made on the basis of actual fuel substance. It is possible, therefore, that the net losses in heating value may be slightly less than are reported, since the actual weight of fuel substance present may be somewhat greater, although its heat value is less than when the coal was stored.

TABLE 23.—*Loss in heat value of Sheridan (Wyo.) coal during storage.*

	As received.					"Unit coal" basis.		Loss in B. t. u.
	Moisture.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	
	Per cent.	*Per cent.*	*Per cent.*					*Per cent.*
Bin 1—open:								
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,266	.....
After 3 months	21.06	9.83	1.05	4,915	8,847	7,174	12,913	2.66
After 9 months	20.39	8.62	.88	4,982	8,968	7,070	12,726	4.07
After 2¾ years	18.75	7.24	.76	5,250	9,450	7,135	12,843	3.19
Bin 2—closed:								
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,266	.....
After 3 months	20.93	10.36	.81	4,907	8,833	7,202	12,964	2.28
After 9 months	17.57	10.00	1.08	5,034	9,061	7,010	12,618	4.88
After 2¾ years	15.32	7.96	.85	5,420	8,756	7,094	12,769	3.75
Bin 3—closed, coal moistened:								
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,236	.....
After 3 months	22.00	9.59	1.00	4,821	8,678	7,109	12,796	3.54
After 9 months	18.86	7.90	1.01	5,129	9,232	7,053	12,695	4.30
After 2¾ years	15.62	9.70	.90	5,244	9,439	7,076	12,737	3.99
Bin 4—deep, closed:								
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,236	.....
After 3 months	20.38	9.00	.91	5,116	9,209	7,303	13,145	.91
After 9 months	18.78	6.56	.80	5,221	9,384	7,033	12,659	4.57
After 2¾ years	12.53	9.84	.94	5,381	9,686	6,982	12,568	5.26
Bin 5—closed, deep, screenings:								
As stored	20.82	11.62	1.21	4,915	8,847	7,355	13,199	.....
After 3 months	20.65	10.63	.88	4,582	8,788	7,166	12,899	2.57
After 9 months	18.21	10.87	.94	4,974	8,953	7,066	12,719	3.93
After 2¾ years	16.20	11.99	.92	4,975	8,955	6,990	12,582	4.96

Three mine samples were taken from the Dietz mines at different times, one from No. 2 mine, April 9, 1909, one from No. 4 mine,

November 22, 1911, and one from No. 2 mine, November 22, 1911. The analyses of these three mine samples are given below for comparison with those of the car samples taken when the coal was stored. These samples represent the average commercial output of the mines. The interval of two and one-third years between these samples gives a check on the uniformity of the sampling and analytical methods.

TABLE 24.—*Analyses of samples of coal from Dietz mines, Sheridan, Wyo.*

Mine from which sample was taken.	As received.					"Unit coal" basis.[a]	
	Moisture.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.
	Per cent.	*Per cent.*	*Per cent.*				
No. 2	23.55	4.98	0.74	5,232	9,418	7,367	13,261
No. 2	21.64	8.99	1.28	5,058	9,104	7,358	13,244
No. 4	22.85	8.46	1.18	4,985	8,973	7,219	13,174

[a] Moisture, sulphur, and ash-free basis.

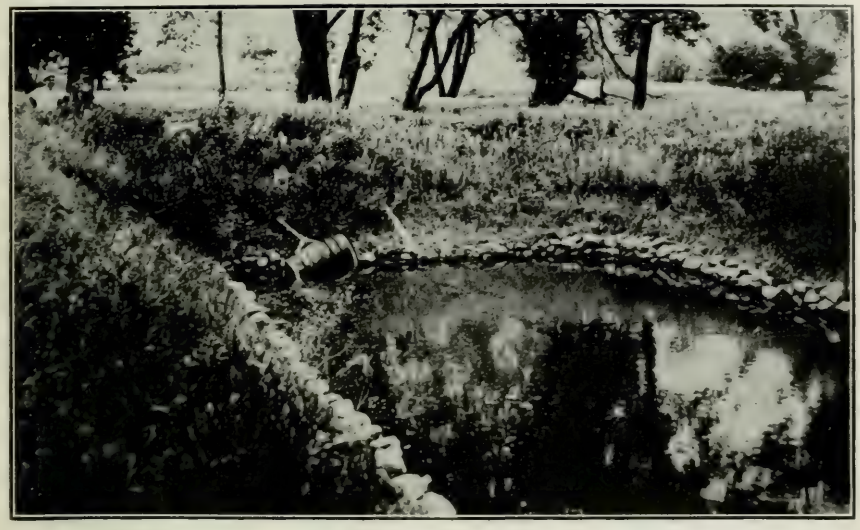
After nine months (Sept. 1, 1908), a photograph was taken of bins 1 and 2, showing the effect of the closed bin as compared with the open in preventing slacking of lumps. (See Pl. V, *B*.) After two and three-fourths years (September, 1910) the coal in each bin was photographed at rather close range, before and after removal from the bins, so as to show its physical appearance both on the surface and after being thoroughly mixed by rehandling. (See Pls. V, *C*, VI, and VII.) Careful observations also were made at this time to determine the extent of the slacking in each bin.

Bin 1 (open, coal piled 5 feet deep): A fairly uniform layer, 8 inches to 12 inches thick, of closely packed, finely disintegrated coal (see Pl. VI, *A*) had formed over the surface. Below that the coal was practically in the same condition as when stored. Near the center, especially, the lumps were harder and brighter than at the sides, and harder also than those in bins 2, 3, and 4. (See Pl. VII.)

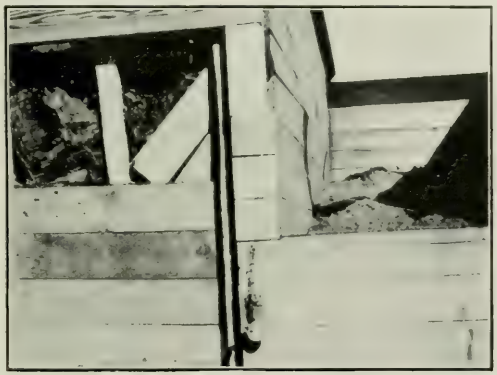
Bin 2 (closed, coal piled 6 feet deep): Coal had slacked somewhat on the surface (Pl. VI, *B*), but had not completely disintegrated, as had coal in bin 1. The lumps all through the bin were of a dull color and showed more or less cracking. (See Pl. VII, *B*.) They broke up badly on handling.

Bin 3 (closed, 6 feet deep, coal moistened): Lumps had cracked and weakened more than in bin 2; otherwise appearance was nearly the same.

Bin 4 (closed, run-of-mine coal, 15 feet deep): Physical appearance of coal in the upper two-thirds of bin was much the same as in bin 2, that is, the lumps were still more or less intact, but were cracked and weakened so that they broke up badly on handling. The coal in the lower third of the pile seemed to be somewhat brighter and firmer.



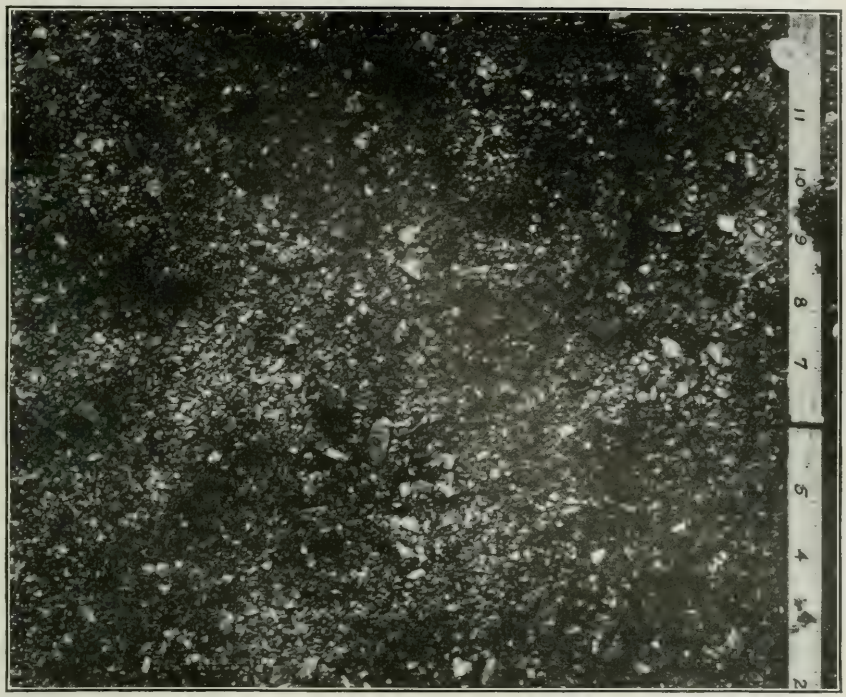
A. METHOD OF SUBMERGING BARRELS OF PITTSBURGH COAL AT ANN ARBOR, MICH.



B. SUBBITUMINOUS COAL STORED AT SHERIDAN, WYO., AFTER 2¾ YEARS.

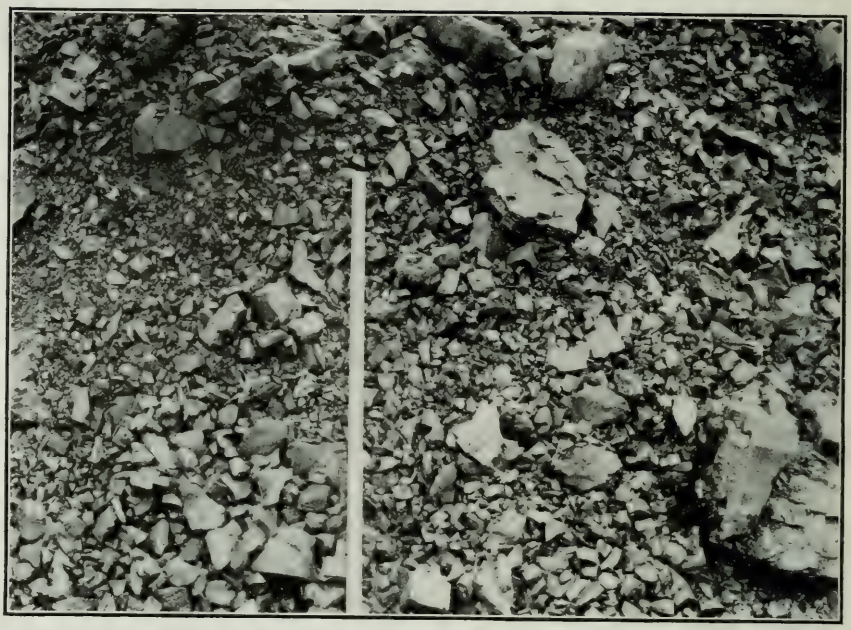
Bin 1 on right, bin 2 on left. Note effect of closed bin on preserving lumps.

C. SUBBITUMINOUS COAL FROM BIN 1, AFTER 2¾ YEARS' STORAGE AT SHERIDAN, WYO.



A. SUBBITUMINOUS COAL IN BIN 1, AT SHERIDAN, WYO., AFTER 2¾ YEARS' STORAGE.

B. SUBBITUMINOUS COAL IN BIN 2, AT SHERIDAN, WYO., AFTER 2¾ YEARS' STORAGE.



A. NEAR VIEW OF COAL FROM BIN 1, AFTER REMOVAL. NOTE SIZE OF LUMPS. (SHERIDAN, WYO.)

B. NEAR VIEW OF COAL FROM BIN 2, AFTER REMOVAL. NOTE SIZE OF LUMPS. (SHERIDAN, WYO.)

Bin 5 (closed, screenings, 15 feet deep): Coal apparently was less weathered than in bin 4; seemed to have been very little altered in lower two-thirds of pile.

Referring to the results in Table 23, during the first three months, the greatest loss, 3.54 per cent, was in the shallow bin, bin 3, where the coal had been moistened. Then followed, in order, bin 1, 2.66 per cent; bin 5, 2.57 per cent; bin 2, 2.28 per cent; and bin 4, 0.91 per cent. The added moisture seemed to increase the deterioration. After nine months, however, the order was changed, bin 2, the closed, shallow bin, showing the greatest loss, 4.88 per cent; and following that, in order, bin 4, 4.57 per cent; bin 3, 4.30 per cent; bin 1, 4.07 per cent; bin 5, 3.93 per cent. During the hot, dry weather of summer, the deterioration had been more or less equalized in all the bins. Bin 1, the open bin, seems to have been protected by its surface layer of slack fully as well as the others were by the roof of the bins.

The seemingly greater loss of heat value at this nine months' stage in bins 1, 2, and 3 than was shown two years later in the same bins is easily explained by the fact that the nine months' samples were grab samples taken 8 to 12 inches below the surface, where greater weathering could occur, whereas the $2\frac{3}{4}$-year samples were representative of the entire lot in each bin and included parts from the interior that were scarcely weathered at all.

After $2\frac{3}{4}$ years bin 4, the deep closed bin, showed the greatest loss, 5.26 per cent; then followed, in order, bin 5, 4.96 per cent; bin 3, 3.99 per cent; bin 2, 3.75 per cent; and bin 1, 3.19 per cent.

CONCLUSIONS.

Evidently Sheridan coal under the conditions of these tests loses 3 to 5.5 per cent of its heat value in about three years' storage, the greater part (70 to 80 per cent) of this loss being in the first nine months. During the period of $2\frac{3}{4}$ years the deep bins suffered the greatest loss, probably because their sides offered greater surface for access of air than those of the small bins. The latter became covered with a 12-inch layer of fine slack that helped to protect the layers beneath from oxidation. In the deep bins, the lumps became badly cracked, but retained their form sufficiently to give more ready access of air, and thus permit greater oxidation.

In the storage of Sheridan coal for more than three months, covering the bins is not as advantageous as the use of air-tight bottoms and sides (of concrete, for example), and the accumulation of a protecting layer of fine slack on the surface. The deterioration of Sheridan coal in heat value can probably in this manner be kept below 3 per cent in one year, and will probably not increase to more than 4 per cent in two or three years if the coal remains undisturbed.

Physical deterioration (slacking) is also largely prevented in the under portions by the formation of a closely packed layer of slack, at least 12 inches thick on the surface.

Although no indications of spontaneous heating were noted in the tests herein described, it is found in practice to be dangerous, on account of dangerous heating, to store Sheridan coal in piles greater than about 10 feet in depth or width. In large masses of coal radiation of spontaneously developed heat is restricted to a dangerous degree. Submergence under water would probably prove particularly advantageous as a means of safely storing subbituminous coal of the Sheridan type.

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BULLETIN 85. Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913, by A. C. Fieldner, H. I. Smith, A. H. Fay, and Samuel Sanford. 1914. 444 pp., 2 figs.

BULLETIN 116. Methods of sampling delivered coal, and specifications for the purchase of coal for the Government, by G. S. Pope. 1916. 64 pp., 5 pls., 2 figs.

BULLETIN 119. Analyses of coals purchased by the Government during the fiscal years 1908–1915, by G. S. Pope. 1916. 118 pp.

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TECHNICAL PAPER 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.

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TECHNICAL PAPER 113. Some properties of the water in coal, by H. C. Porter and O. C. Ralston. 1916. 30 pp., 3 figs.

TECHNICAL PAPER 140. The primary volatile products of the carbonization of coal; a sequel to Bulletin 1, The volatile matter of coal, by G. B. Taylor and H. C. Porter. 1915. 59 pp., 1 pl., 25 figs.

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